UNIVERSITEIT GENT

FACULTEIT INGENIEURSWETENSCHAPPEN

EBU Forecast 2007
Coverage and parameter evaluation of a DVB-H trial in Ghent

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VRT (Flemish Radio and Television Network)

Overview

- Context and objectives
- Transmitting DVB-H system in Ghent
- Method
- Coverage
- Parameter evaluation
- Conclusions

Context and objectives

- **DVB-H**
  - Digital Video Broadcasting-Handheld
  - Based on ETSI standards
    - **EN 300 744**
    - **EN 302 304**
  - High data rate broadcast access for hand-held terminals
  - Audio, video, file downloads,...
  - Data rates up to 15 Mbps

Context and objectives

- **Objectives**
  - Coverage
    - **Model for City of Ghent**
  - Parameter evaluation: investigation of influence on performance of
    - **Different reception conditions**
      - Portable indoor/outdoor, mobile
    - **6 different modulation schemes**
    - **6 different MPE-FEC rates**

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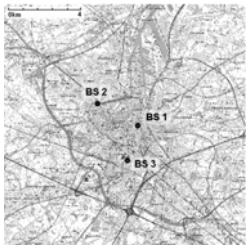
Characteristics of DVB-H system

- **Single frequency network (SFN)**
- **Center frequency**
  - **602 MHz**
- **Channel bandwidth**
  - **8 MHz**
- **3 base station (BS) antennas**
  - h_{BS} = 64 m, 57 m, 63 m
  - Kathrein 759 13855 antennas
  - ERP = 6 kW, 2.8 kW, 7.5 kW
- **Requirement**
  - Throughput of 10 Mbps
  - 16 QAM 1/2, MPE-FEC 7/8



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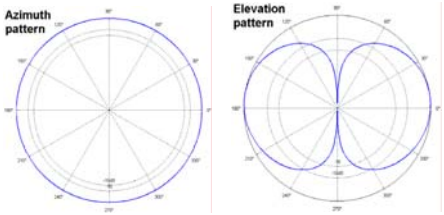
Receiver

- On vehicle roof
- Rx vertically polarised
- Height
  - h_{Rx} = 2.85 m
- Speed
  - 25 km/h [ITU 1708]

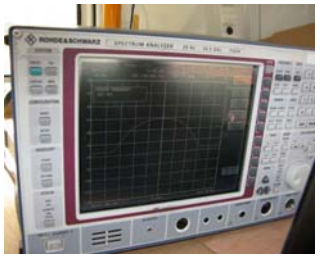
Receiver

- **Receiver antenna**
  - Jaybeam 7511
  - Gain = 0 dBd (2.15 dBi)



Processing

- **Spectrum analyzer**
  - R&S FSEM 20
  - Frequency range: 20 Hz – 26.5 GHz
  - Output sampled and stored on laptop

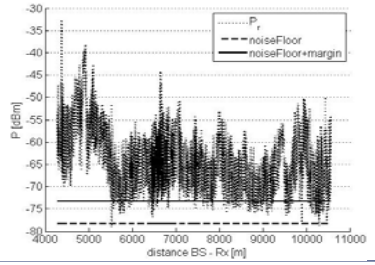


Processing

- **Data processing**
  - 602 MHz
  - Measurement along a track
  - Noise floor ≈ -58, -68, -78 dBm (ref. level = 0, -10, -20 dBm)
  - Margin = 5 dB
  - 1 167 985 samples maintained for processing
  - Small-scale fading removal
    - ± 1.35 samples per wavelength λ (54 samples/40 λ)
    - Power levels averaged over 40 wavelengths (Lee criterium)
  - Averaged power levels used to calculate path loss and E [dBµV/m]

Processing

- **Data processing: measurement track**



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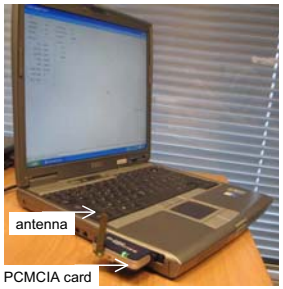
- **Method**
  - Coverage
  - Parameter evaluation
- **Coverage**
- **Parameter evaluation**
- **Conclusions**

Measurement method

- Measurements with a commercial tool and GPS
  - **Laptop and PCMCIA card**
  - **Antenna gain = -5 dBi**
  - **Parameters**
    - C/(N+I) ratio (carrier-to-interference-noise ratio)
    - FER (Frame Error Rate)
    - MFER (Multi-Protocol Encapsulation FER)
    - Location
    - Speed
    - Electric field strength
  - **Sample every 0.5 s**

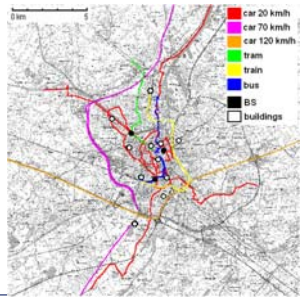


Investigated scenarios

- Different reception conditions: 9 scenarios
  - **Portable reception**
    - Scenario I = outdoor walking (20 different routes)
    - Scenario II = indoor standing (13 different buildings)
    - Scenario III = indoor walking (13 different buildings)
  - **Mobile reception**
    - Scenario IV = car 20 km/h (6 routes, 70.5 km)
    - Scenario V = car 70 km/h (3 routes, 37.5 km)
    - Scenario VI = car 120 km/h (2 routes, 50 km)
    - Scenario VII = train
    - Scenario VIII = tram
    - Scenario IX = bus
- Several thousands of measurement points for each scenario

Investigated scenarios

- Routes for mobile reception
  - **Outdoor walking: 20 routes**
  - **Car 20 km/h: 70.5 km**
  - **Car 70 km/h: 37.5 km**
  - **Car 120 km/h: 50.0 km**
- Buildings for indoor measurements
  - **13 buildings**
- 3 base stations BS



Investigated schemes

- **"FFT, guard interval, modulation scheme, MPE-FEC"**
- **4K, 1/8, 16-QAM 1/2, MPE-FEC 7/8**
- **4K, 1/8, 16-QAM 1/2, MPE-FEC 5/6**
- **4K, 1/8, 16-QAM 1/2, MPE-FEC 3/4**
- **4K, 1/8, 16-QAM 1/2, MPE-FEC 2/3**
- **4K, 1/8, 16-QAM 1/2, MPE-FEC 1/2**
- **4K, 1/8, 16-QAM 1/2, MPE-FEC 67/68**
- **4K, 1/8, QPSK 1/2, MPE-FEC 7/8**
- **4K, 1/8, QPSK 2/3, MPE-FEC 7/8**
- **4K, 1/8, 16-QAM 2/3, MPE-FEC 7/8**
- **4K, 1/8, 64-QAM 1/2, MPE-FEC 7/8**
- **4K, 1/8, 64-QAM 2/3, MPE-FEC 7/8**

Measurements in car, train, tram and bus. Measurements portable indoor and outdoor.

Influence MPE-FEC

Influence modulation scheme

Parameters

- Parameters used for analysis
  - **%Valid reception: the percentage of the time that the receiver is locked and receives either correct, or corrected tables**

- $\frac{C}{N+I}|_{MFER\ 5\%}$: **the minimal value of C/(N+I) for which the MFER is at most 5%**
- $\frac{C}{N+I}|_{FER\ 5\%}$: **the minimal value of C/(N+I) for which the FER is at most 5%**
- $\Delta C_{5\%}$: $\frac{C}{N+I}|_{FER\ 5\%} - \frac{C}{N+I}|_{MFER\ 5\%}$
- $\Delta E_{5\%}$: $E|_{FER\ 5\%} - E|_{MFER\ 5\%}$

Overview

General model

- **Path loss**
  - Path loss (PL) = all possible elements of loss associated with the interaction between the propagating wave and any objects between T_x and R_x antenna [dB]

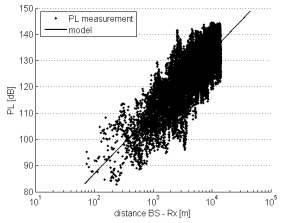
$$PL(d)=\underbrace{P_0+10n\log(d/d_0)}_{\text{median}}+\underbrace{\chi}_{\text{variation}}$$

  - P_0 = reference power at d_0 [dBm]
  - d_0 = reference distance (100 m)
  - d = distance from BS [m]
  - n = path-loss exponent [-]
  - χ = normal shadowing fading variation [dB] with standard deviation σ [dB]

General model

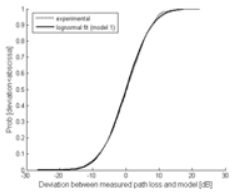
$$PL(d)=P_0+10n\log(d/d_0)+\chi$$

- **Minimization of root-mean-square deviation (RMS) of measurement points**
- **Model**
  - Fit with two parameters P_0 and n
  - P_0 = 86.8 dB
    n = 2.34
    σ = 6.18 dB



General model

- **Cumulative distribution function (cdf): chance that χ is lower than abscissa**
- **Comparison of cdf of deviation of experimental data from model with cdf of normal distribution**
- **Definitions**
  - σ [dB]: standard deviation of difference between between experimental data and model
  - σ_{fit} [dB]: standard deviation of normal fit to cdf of difference between experimental data and model
- **σ = 6.18 dB, σ_{fit} = 6.17 dB**
- **Excellent agreement!**

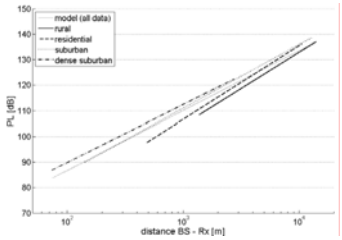


Models for different environments

- **Classification based on environmental characteristics**
  - Dense suburban (narrow streets (<10 m), terraced houses)
  - Suburban (street width between 10 m and 15 m)
  - Residential (street width > 15 m, gardens)
  - Rural (mostly open, at least on one side of the street, few houses)

Different environments

- Highest path loss for denser environments
- Model with all data in between other models

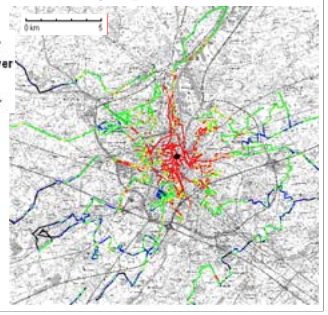


Coverage of a single transmitter

- Equivalent electric field strength [dBµV/m]

@ 2.85 m

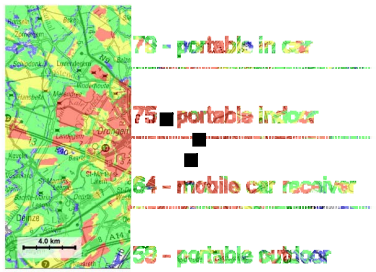
- 64.5 dBµV/m – portable outdoor
- 69.5 dBµV/m – mobile car receiver
- 80.5 dBµV/m – portable indoor
- 84.5 dBµV/m – mobile inside car
- < 64.5 dBµV/m



Coverage: Ghent

- At h_{Rx} = 1.5 m
- Based on experiments
- 16-QAM ½
- VRT

dBµV/m
- 79 - portable in car
- 75 - portable indoor
- 64 - mobile car receiver
- 59 - portable outdoor



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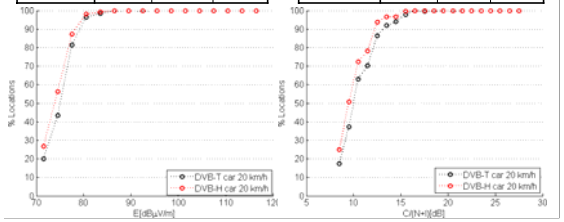
  - 16-QAM 1/2, MPE-FEC 7/8, 4K, GI = 1/8
    - Example: car 20 km/h
    - Comparison of different reception conditions
  - Influence of MPE-FEC rate
  - Influence of modulation scheme
- Conclusions

Example: car 20 km/h

- FER and MFER
- %Locations = ratio valid tables and total number of tables
- Gain MPE-FEC 7/8: 0.61dB for E and 1.82 dB for C/(N+I)

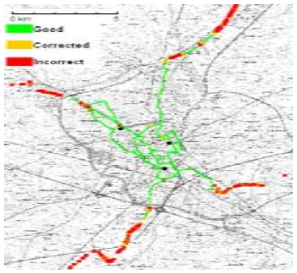
E [dBµV/m]	0%	1%	5%
FER	95.5	84.6	80.3
MFER	86.5	82.9	79.7

C/(N+I) [dB]	0%	1%	5%
FER	21.5	16.0	14.8
MFER	16.5	15.3	12.9



Car 20 km/h

- Reception quality in Ghent in car driving at 20 km/h
- Tables received
  - **Correct: green**
  - **Corrected: orange**
  - **Incorrect: red**



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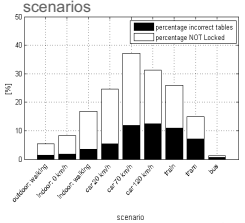
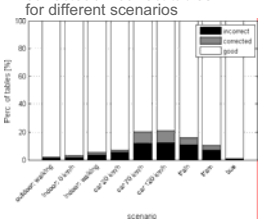
Comparison of different reception conditions

- Percentage not locked / incorrect tables for different scenarios



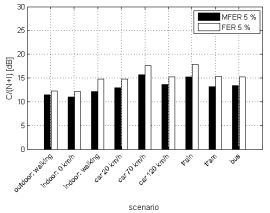
- Percentage of good / corrected / incorrect tables for different scenarios



- Highest percentage not locked / incorrect tables for car 70-120 km/h and train
  - **More difficult reception conditions**
- Be careful with comparison of scenarios
  - **Different locations, different number of measurement points**

Comparison of different scenarios

- Higher C/(N+I) required for more difficult reception conditions
  - **Higher speed**
  - **Reception in trains**
  - **…**
- Example: MFER 5%
  - **Outdoor walking: 11.4 dB**
  - **Car at 70 km/h: 15.7 dB**

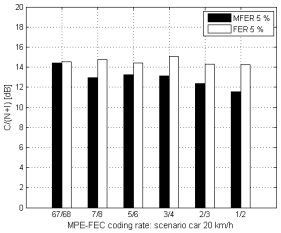


- Gain of 0.9 to 2.6 dB when using MPE-FEC 7/8

Overview

Influence MPE-FEC

- Influence on C/(N+I) (car 20 km/h)
  - **FER and MFER 5% values for different MPE-FEC rates**
  - **FER 5% values rather constant, also for other scenarios**
  - **The more MPE-FEC coding, the lower the required MFER 5% value**



Influence MPE-FEC

- Average over all scenarios
- Influence on % correct, corrected, incorrect tables, %lock, %valid reception
  - **%Correct tables ± constant**
  - **%Corrected tables higher when MPE-FEC rate higher**
  - **%Incorrect tables lower when MPE-FEC rate higher**
  - **%Lock slightly higher when MPE-FEC rate higher**
  - **%Valid reception higher when MPE-FEC rate higher**

MPE-FEC rate	%Correct tables	%Corrected tables	%Incorrect tables	%Lock	%Valid reception
67/68	93.98	0.37	5.64	88.56	83.56
7/8	90.28	3.59	6.13	87.73	82.35
5/6	91.90	2.56	5.53	88.83	83.92
3/4	91.52	3.71	4.77	88.50	84.28
2/3	92.02	4.55	3.43	91.61	88.47
1/2	92.21	5.05	2.73	90.38	87.91

Influence MPE-FEC

Gain ↗

scenario	MPE-FEC gain [dB]	67/68					
Outdoor walking (I)	ΔC5% [dB]	0					2.65
	ΔE5% [dB]	0	1.95	0	0	3.65	4.34
Indoor standing (II)	ΔC5% [dB]	0	1.13	0.48	0.2	0.58	1.03
	ΔE5% [dB]	0.11	1.7	1.48	0.58	1.32	3.22
Indoor walking (III)	ΔC5% [dB]	0.57	2.62	1.26	0.82	2.11	2.73
	ΔE5% [dB]	0.69	1.95	0.62	0.99	3.08	3.58
Car 20 km/h (IV)	ΔC5% [dB]	0.12	1.82	1.13	1.94	1.96	2.70
	ΔE5% [dB]	0.12	0.61	0.97	2.00	2.76	3.37
Car 70 km/h (V)	ΔC5% [dB]	0.38	1.91	1.36	2.96	1.62	2.68
	ΔE5% [dB]	0.003	2.12	1.61	2.86	3.2	3.62
Car 120 km/h (VI)	ΔC5% [dB]	0	1.65	1.54	2.68	3.56	2.92
	ΔE5% [dB]	0.55	2.05	2.14	3.61	2.76	3.09
Train (VII)	ΔC5% [dB]	0	2.58	1.95	1.6	1.9	3.39
	ΔE5% [dB]	0	3.34	0.64	2.9	3.45	3.34
Tram (VIII)	ΔC5% [dB]	0	2.23	1.6	2.74	1.04	1.83
	ΔE5% [dB]	0.04	0.83	2.04	2.53	2.35	2.97
Bus (IX)	ΔC5% [dB]	0	1.88	-	0.75	-	1
	ΔE5% [dB]	0	1.89	-	-	-	2.73
Average (I-VIII)	ΔC5% [dB]	0.13	1.85	1.31	1.71	1.89	2.49
	ΔE5% [dB]	0.19	1.82	1.19	1.93	2.82	3.44

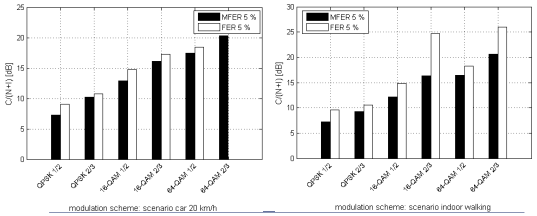
Influence MPE-FEC

- More MPE-FEC corresponds with a larger gain
  - **67/68: on average 0.13 dB gain for C/(N+I), maximum gain is 0.57 dB**
  - **1/2: on average 2.49 dB gain for C/(N+I), maximum gain is 3.39 dB (in train)**
  - **7/8: maximum gain for C/(N+I) is 2.62 dB (indoor walking)**
  - **5/6: maximum gain for C/(N+I) is 1.95 dB (in train)**
  - **3/4: maximum gain for C/(N+I) is 2.96 dB (in car at 70 km/h)**
  - **2/3: maximum gain for C/(N+I) is 3.56 dB (in car at 120 km/h)**
- Largest gains for car 70 km/h, car 120 km/h, and train
- Lowest gains for indoor standing and outdoor walking
- Useful for practical coverage evaluation
- Gains for E larger than for C/(N+I), because of higher range of measurements

Overview

Influence modulation scheme

- Influence on C/(N+I) (car 20 km/h, indoor walking)
  - **FER and MFER 5% values for different modulation schemes**
  - **Higher required FER and MFER 5% values for higher modulation schemes**



Influence modulation scheme

- Average over all scenarios
- Influence on % correct, corrected, incorrect tables, % lock, % valid reception
  - **%Correct tables lower for higher modulation scheme**
  - **%Corrected tables higher for higher modulation scheme**
  - **%Incorrect tables higher for higher modulation scheme**
  - **%Lock lower for higher modulation scheme**
  - **%Valid reception lower for higher modulation scheme**

Modul. scheme	%Correct tables	%Corrected tables	%Incorrect tables	%Lock	%Valid reception
QPSK 1/2	96.71	1.06	2.23	97.61	95.43
QPSK 2/3	89.20	3.46	7.34	85.49	79.21
16-QAM 1/2	90.28	3.59	6.13	87.73	82.35
16-QAM 2/3	82.39	5.94	11.67	80.64	71.22
64-QAM 1/2	85.33	5.36	9.31	80.51	73.01
64-QAM 2/3	67.42	13.07	19.52	68.49	55.12

Influence modulation scheme

FER/MFER 5% ↗

scenario	MFER/FER 5% values	QPS					M 2/3
Outdoor walking (I)	FER 5% [dB]	8.68					
	MFER 5% [dB]	8.50					20.38
Indoor standing (II)	FER 5% [dB]	7.35	9.32	12.11	14.69	19.83	19.22
	MFER 5% [dB]	7.35	7.48	10.99	14.28	18.31	17.93
Indoor walking (III)	FER 5% [dB]	9.63	10.52	14.82	24.65	18.26	25.93
	MFER 5% [dB]	7.19	9.27	12.20	16.38	16.45	20.65
Car 20 km/h (IV)	FER 5% [dB]	8.07	10.75	14.76	17.29	19.46	-
	MFER 5% [dB]	7.28	10.23	12.94	16.11	17.45	20.28
Car 70 km/h (V)	FER 5% [dB]	7.17	14.87	17.61	21.78	21.82	-
	MFER 5% [dB]	6.50	9.34	15.70	15.60	19.55	-
Car 120 km/h (VI)	FER 5% [dB]	7.32	14.32	15.23	22.17	19.31	-
	MFER 5% [dB]	6.89	12.63	13.58	15.70	19.01	-
Train (VII)	FER 5% [dB]	8.75	13.93	17.83	-	19.66	-
	MFER 5% [dB]	8.35	10.29	15.24	19.42	19.43	21.12
Tram (VIII)	FER 5% [dB]	>6.50	11.35	15.37	17.37	-	24.10
	MFER 5% [dB]	>6.50	10.88	13.14	16.21	17.97	20.76
Bus (IX)	FER 5% [dB]	<10.50	8.35	15.25	<14.50	26.75	-
	MFER 5% [dB]	<10.50	<7.50	13.38	<14.50	17.80	20.29
Average (I-VIII)	FER 5% [dB]	8.16	11.69	15.01	19.33	19.07	22.75
	MFER 5% [dB]	7.07	9.82	13.15	15.92	16.91	19.78

Influence modulation scheme

- Higher modulation scheme corresponds with a higher required C/(N+I)
  - **QPSK 1/2: MFER 5% values on average 7.07 dB**
  - **64-QAM 2/3: MFER 5% values on average 19.78 dB**

- When changing from QPSK to 16-QAM, requirement is 6 dB higher
- When changing from 16-QAM to 64-QAM, requirement is at least 3.5 dB higher

- When changing inner code rate from 1/2 to 2/3, requirement 2 to 3 dB higher

- Most difficult reception conditions are car 70 km/h, car 120 km/h, and train

Conclusions (1)

- **Path loss model presented**
- **Lognormal**
  - Validated by analyzing cdf
- **Different propagation environments categorized**
  - Higher path losses for denser environments
- **Selection of suitable scheme**
  - 16-QAM 1/2 with MPE-FEC 7/8, 4K mode and guard interval 1/8
  - 9.68 Mbps

Conclusions (2)

- **Evaluation of the performance of DVB-H system**
- **9 different reception conditions**
- **Results for 16-QAM 1/2 MPE-FEC 7/8, 4K, GI = 1/8**
  - Most difficult scenarios are train and car 70-120 km/h
- **MPE-FEC gain**
  - See values in table for coverage calculations
  - Average MPE-FEC gain for C/(N+I) varies between 0.13 dB (67/68) and 2.49 dB (1/2)
- **Modulation scheme**
  - Average MFER 5% value for C/(N+I) varies between 7.07 dB (QPSK 1/2) and 19.78 dB (64-QAM 2/3)
  - Changing inner code rate from 1/2 to 2/3: requirement 2 to 3 dB higher
- **Acknowledgment: MADUF project/IBBT (Flemish DVB-H trial)**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